

## SPECIFICATION

## IMAGE ENCODER AND IMAGE DECODER

## FIELD OF THE INVENTION

The present invention generally relates to the field of digital image processing and, more specifically, to an image coding device for encoding digital image data with high efficiency and an image decoding device for decoding coded data encoded by the image coding device.

## BACKGROUND OF THE INVENTION

Flash Pix format specification version 1.0 has been proposed as an image format for converting natural image data into digital data suitable for computer processing.

This format specification permits a plurality of data with different resolutions to be stored together therein so that any data suited to an actual display and/or printing device can be selected and taken-out promptly in response to a user's request. Furthermore, each image is divided into tiles arranged in the format that allows the user to select only a necessary data portion of the image and process it in an enlarged or reduced size with a reduced processing load.

Referring to Figures 1 and 2, an image coding device for encoding an image according to the flash pix format is described as follows. In Fig. 1, images are shown in different reduced











given rule.

For the Flash Pix method using a plurality of coded data sets separately provided for respective images of different resolution levels, the image processing load such as enlargement or contraction of the image can be reduced, but the data size is increased to 1.4 times.

For wavelet-transform coding method, data with different resolution levels can be easily decoded from a single set of compressed and coded data for an original image size and, therefore, no increase in the data size takes place.

When the wavelet-transform coding system utilizes the method of decomposing an image into tiles and encoding the image data on a tile-by-tile basis, which is used in the flash-pix system (to reduce the processing load by selectively processing only necessary tiles in case of processing a particular part of the image), however, this arises the above-described problem since filters may stick from the boundary of respective tiles.

In other words, the flash pix system using the JPEG coding can easily perform coding of each tile owing to the closed property of coding in each tile, while the wavelet-transform coding system can not effectively use the above tile-by-tile coding-and-managing method because the processing causes the extrusion of filters out of respective tiles.

In addition, the conventional wavelet-transform coding system must have a memory sufficient for storing an output of the wavelet-transform portion 31 (Fig. 3), i.e., all wavelet









Figure 18 is a block diagram of an image coding device according to an embodiment 7 of the present invention.

Figure 19 is view for explaining the operation of an image coding device according to the embodiment 7 of the present invention.

Figure 20 is a block diagram of an image decoding device according to an embodiment 8 of the present invention.

Figure 21 is a block diagram of an image decoding device according to an embodiment 9 of the present invention.

Figure 22 is a block diagram of an image coding device according to an embodiment 10 of the present invention, with a view for explaining the operation of the same device.

Figure 23 is a block diagram of an image decoding device according to an embodiment 11 of the present invention, with a view for explaining the operation of the same device.

Figure 24 is a block diagram of an exemplary image coding device according to an embodiment 12 of the present invention.

Figure 25 is a block diagram of another exemplary image coding device according to the embodiment 12 of the present invention.

Figure 26 is a block diagram of another exemplary image coding device according to the embodiment 12 of the present invention.

Figure 27 is a block diagram of an exemplary image decoding device according to an embodiment 13 of the present invention.

Figure 28 is a block diagram of another exemplary image

decoding device according to the embodiment 13 of the present invention.

Figure 29 is a block diagram of another exemplary image decoding device according to the embodiment 13 of the present invention.

Figure 30 is a block diagram of an exemplary image coding device according to the embodiment 14 of the present invention.

Figure 31 shows an exemplified bit stream in an image coding device according to the embodiment 14 of the present invention.

Figure 32 is a block diagram of another exemplary image coding device according to the embodiment 14 of the present invention.

Figure 33 is a block diagram of another exemplary image coding device according to the embodiment 14 of the present invention.

Figure 34 is a block diagram of another exemplary image coding device according to the embodiment 14 of the present invention.

Figure 35 is a block diagram of an image decoding device according to an embodiment 15 of the present invention.

Figure 36 is a block diagram of an exemplary image coding device according to an embodiment 16 of the present invention, with a view for explaining the operation of the same device.

Figure 37 is a block diagram of another exemplary image coding device according to the embodiment 16 of the present invention.



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103 quantizes wavelet transform coefficients and an entropy coding portion 104 performs entropy coding of the coefficients to obtain coded data of the tile "i".

The entropy coding can be achieved by using a known Huffman coding method or arithmetic coding method. The wavelet transform portion 102, quantizing portion 103 and entropy coding portion 104 composes a so-called wavelet transform coding portion 105.

On the other hand, a management information generating portion 106 generates information for identifying and managing tiles and subbands by using information on spatial locations of each tile from the tile decomposition portion 101 and information on each subband from the wavelet transform coding portion 105. The management information is utilized by a coded data integration portion 107.

Using the management information from a management information generating portion 106, the coded data integration portion 107 arranges and integrates information on the coded data from the entropy coding portion and adds the management information to a bit stream to generate coded data.

Management of the coded data according the tiles and subbands is needed for achieving decoding of a coded image at different resolution levels as shown in Fig. 1 or a particular tile or tiles of the coded image.

Figure 10 shows an example of a bit stream of coded data produced in the above-described manner. The bit stream is

composed of a header for managing information on a whole bit stream and information on each tile. Information for each tile consists of a tile header for managing the tile information and coded information representing a tile image encoded by the wavelet transform coding portion 105.

The tile header includes information on bit positions corresponding to respective subbands. A bit sequence corresponding to necessary one of the subbands can be found by accessing this information.

The structure of bit streams used in the system of the present invention is not limited to that shown in Fig. 10. For example, a sequence (I) A of Fig. 11 is similar to the sequence of Fig. 10, while a sequence (II) of Fig. 11 has the form in which each subband for a tile is separated and rearranged with a tile header added thereto. The latter sequence (II) allows the system to quickly reproduce a desirable contracted image by accessing only necessary tile or tiles in the sequence.

An image coding device according another embodiment 2 of the present invention will be described as follows. The image coding device of the embodiment 2 is similar in construction to the embodiment 1 shown in Fig. 8 but differs from the embodiment 1 described above with the figure 8 by the operation of the tile decomposition portion 101, which will be described below with reference to Fig. 12.

While the tile decomposition portion 101 of the embodiment 1 decomposes an image into tiles each of N pixels by M pixels

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and outputs only image data within each tile to the wavelet transform portion 102, the tile decomposition portion 101 of embodiment 2 outputs image data obtained by multiplying the original image by a suitable window function.

For example, in case of extracting a tile "ij", the output of the tile decomposition portion 101 is a result of multiplying the original image data by a window function  $FX_i$  in the horizontal direction and by a window function  $FY_j$  in the vertical direction.  $i$  denotes a horizontal tile number and  $j$  denotes a vertical tile number.

This means that the output of the tile decomposition portion 101 represents a weighted result of multiplying a shaded image portion (Fig. 12) by a weight corresponding to window functions. Window functions are such that a total of functions over a whole area is equal to 1. Window functions satisfying the following conditions are used.

$$\sum FX_i(x)=1 \quad (0 \leq x \leq w)$$

$$\sum FY_j(y)=1 \quad (0 \leq y \leq h)$$

where,  $w$  is the width of the original image,  $h$  is the height of the original image,  $x$  and  $y$  are the axes of abscissa and ordinate, respectively, with the origin at the top right corner of the original image.

A total of the functions  $FX_i(x)$  is taken for  $i$  and  $FY_j(y)$  is taken for  $j$ . In Fig.12,  $FX_{i-1}$ ,  $FX_i$ ,  $FXY_i$ ,  $FY_j$ ,  $FY_{j+1}$  are exemplary functions satisfying the above conditions.

In consequence of the extraction of data by applying window



functions, the output of the tile decomposition portion 101 includes pixels of a tile  $ij$  plus peripheral pixels weighted with the window function values.

An image decoding device for decoding coded data from the image coding device of the embodiment 1 will be now described as an embodiment 3 of the present invention. Figure 13 is a block diagram of the image decoding device according to the embodiment 3.

The image decoding device receives coded data from the image coding device described as the embodiment 1 of the present invention. A management data separating portion 111 takes out information for managing tiles and subbands from the received coded data.

A coded data extracting portion 112 selectively extracts coded data of necessary tile and subbands according to the user's request. In the exemplary bit stream shown in Fig. 10, the management information is found in the header and the tile header.

The extracted coded information is entropy-decoded by an entropy decoding portion 113 and inversely quantized by an inverse quantizing portion 114 to produce wavelet-transform coefficients corresponding to the tile to be decoded.

The wavelet-transform coefficients are inversely transformed by an inverse wavelet transform portion 115 to produce a decoded image of the objective tile. The entropy-decoding portion 113, inverse quantizing portion 114

and inverse wavelet-transform portion 115 compose a so-called wavelet-transform decoding portion 116.

A tile combining portion 117 combines together decoded tiles according to the tile managing information to generate a decoded image of the desired area or at a desired resolution.

The decoding process with the bit stream shown in Fig. 10 is as follows. To decode a low-resolution entire image (all tiles), coded data (1-a, 2-a, ..., i-a, ...), which correspond to low-resolution subbands, are decoded in order in respective tile by the wavelet-transform decoding portion 116 according to the tile with referring to subband information included in each tile header.

The low-resolution decoded tiles are then combined by the tile-combining portion 117, thereby a whole low-resolution image is reproduced.

From the low-resolution decoded image, a particular tile "i" can also be reproduced in an enlarged scale with the highest resolution by decoding all the coded information of the i-th tile which correspond to the tile image "i".

Namely, coded information i-b extracted and decoded together with already extracted coded information i-a to obtain the desired decoded image. It is, of-course, possible to reproduce a high-resolution decoded image of all areas by decoding all coded information (all tiles including all subbands).

Thus, the image decoding device can easily decode any



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An image coding device according to another embodiment 5 of the present invention will be described with reference to Fig. 15 showing its construction.

This image coding device differs from the image coding device (embodiment 1) of Fig. 8 by the fact that it does not unconditionally conduct extrapolation of data at the periphery of an objective tile and utilizes another tile adjacent to the tile if such exists.

Like the embodiment 1, this image coding device decomposes an original image into tiles as shown in Fig. 16A at its tile decomposition portion 121 shown in Fig. 15. The image coding device further processes a tile "i" of the image as follows: In a wavelet-transform coding portion 123, image data of the tile "i" is wavelet-transformed through a wavelet-transform filter. In this case, if the filter extrudes from the tile "i" into neighboring tiles and covers part of pixels contained in the neighbors, image data of those pixels in the neighbors are also wavelet-transformed together with the image data of the objective tile "i" by the filter.

Referring to Fig. 16, the objective tile "i" of Fig. 16A is extended by adding necessary shaded parts of neighboring tiles a-h as shown in Fig. 16B and then wavelet-transformed.

An adjacent pixel adding portion 122 realizes the above process by recognizing neighboring tiles around the objective tile according to the tile decomposition information and by adding necessary pixels if the neighbors exist.

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In the shown case, the adjacent pixel adding portion 122 adds to the objective tile "i" all neighboring pixels existing around there and outputs an increased volume of image data to a wavelet transform portion 123. The wavelet transform portion 123 must therefore transform a larger image area data as compared with the wavelet transform portion 102 of the embodiment 1 that transforms a single tile image.

With an increased image data to be transformed, the image coding device requires an enlarged working area for processing the data, resulting in increasing the cost of the device and decreasing the operating speed. Therefore, it is desirable to use another mode for reducing the size of data to be transformed by the wavelet-transform portion.

This mode is such that the additional adjacent area to be added by the peripheral pixel adding portion 122 to an objective tile area is limited to one direction "x" or "y" as shown in Fig. 16C or 16D to reduce the image data to be input to the wavelet transform portion 123.

For example, in case of Fig. 16C, an objective tile is provided with necessary pixels from upper and lower neighboring tiles if they exist. The right and left sides of the objective tile are treated by generating mirror images by folding the inside image of the tile. The case of Fig. 16D differs the above case of Fig. 16C by adding pixels from the right and left neighbors and generating mirror images for its top and bottom sides.



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portion 125 according to the management information outputted from the management portion 127 and then adds the management information to a bit stream to generate a final coded data as shown for example in Fig. 10.

An image coding device according to still another embodiment 6 of the present invention will be described below:

This image coding device is similar in construction to the device of the embodiment 5 described above with reference to Fig. 15 but differs from the latter only by the operation of its peripheral-pixel adding portion 122. The operation of the peripheral-pixel adding portion 122 is described below with reference to Fig. 17.

An objective tile "i" in Fig. 17 is now processed by way of example as follows:

In the embodiment 5, the peripheral-pixel-adding portion 122 added to a tile "i" all pixels necessary for calculating wavelet-transform coefficients for pixels in the objective tile, that is, pixels in areas covered by a filter extending from the objective tile. The adjacent pixel areas are shown as shaded in Fig. 17.

Since distant pixels have a small effect on wavelet transform coefficients in a tile "i", the embodiment 6 adds a result of multiplying peripheral pixels by a suitable weighing function to the tile "i" to reduce the number of pixels to be attached, i.e., lighten the computation work load.

The weighting function is 1 for each pixel near the tile









selectively extracts a necessary part of the coded information meeting the user's demand by a coded data extracting portion 142 according to the management information. Namely, the coded data corresponding to a necessary objective tile(s) having a necessary resolution is extracted by the coded data extracting portion 142.

The extracted coded information is entropy-decoded by an entropy decoding portion 143 and inversely quantized by an inverse quantizing portion 144. Thus, wavelet transform coefficients corresponding to an objective tile to be decoded are now obtained.

The wavelet transform coefficients inversely transformed by an inverse wavelet transform portion 145, thereby a decoded image including peripheral pixels data is produced. The entropy coding portion 143, the inverse quantizing portion 144 and the inverse wavelet transform portion 145 compose a so-called inverse wavelet transform decoding portion 146.

A tile combining portion 147 integrates groups of the decoded tiles according to the management information from the management information-separating portion 141. In this case, a completely decoded image is reproduced with overlaps of decoded tile images at each spatially overlapped portion.

Namely, the embodiment 2 described above with reference to Fig. 12 performed wavelet transform of each tile with adjacent pixels attached thereto. The embodiment 5 uses adjacent pixels in performing wavelet transform of each tile

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as shown in Fig. 16B. Likewise, the embodiment 6 described with reference to Fig. 17 also uses peripheral pixels in wavelet transform of each tile.

In the image coding device according to the embodiment 7, the process using adjacent pixels is not clearly described but the wavelet transform of a whole original image has been done including the processing theoretically equivalent to that made in the embodiment 5.

Therefore, data of peripheral pixels is produced when each tile image is decoded by the wavelet transform decoding portion 146 in Fig. 20 and the decoded adjacent pixels are superposed on respective neighboring tiles by the tile combining portion 147. The superposition of one pixel on another is achieved by additive operation on the pixels.

Another image decoding device is described below as an embodiment 9 of the present invention. Like the above embodiment 8, the input to this embodiment 9 is coded data encoded by any one of the image coding devices being the embodiments 5 to 7. Figure 21 is a block diagram showing the construction of the image coding device according to the embodiment 9.

Referring to Fig. 21, a management information separating portion 151 separately takes out tile-division management information and subband management information from the input coded-data stream, and a coded data extracting portion 152 selectively extracts a necessary part of the coded information



154 in this embodiment, it is not limited to this arrangement and may be placed before the inverse quantizing portion 154.

An image coding device is described below as an embodiment 10 of the present invention. Figure 22E is a block diagram of a portion of this embodiment, which responds to the wavelet transform portion (102 in Fig. 8, 123 in Fig. 15) of the image coding devices according to the embodiments 1, 2, 5 and 6.

Referring to Fig. 22E, a memory 162 is used for storing wavelet transform coefficients divided into subbands by a wavelet transform portion 161. In this case, the memory 162 stores only wavelet transform coefficients corresponding to a tile being currently processed by the wavelet transform portion 161. The processed data are transferred to a quantizing portion (103 in Fig. 8, 124 in Fig. 15) following the wavelet transform portion 161.

Therefore, the memory 162 has no need to store all data for a whole image and is sufficient to store such an amount of data necessary for processing only one tile.

Namely, if wavelet-transformation without tile decomposition is applied to a whole image as shown in Fig. 22A, it is necessary to store all wavelet transform coefficients (Fig. 22B) outputted from the wavelet transform portion 161. In contrast to the above, the decomposition of an image into tiles as shown in Fig. 22C enables the coding device to use a memory for storing only wavelet transform coefficients corresponding to a small image of Fig. 22D, thus realizing a

considerable saving of the memory capacity.

The same effect can be realized in an image decoding device. An image decoding device is described below as another embodiment 11 of the present invention. Figure 23E is a block diagram, which corresponds to the inverse wavelet transform portion (115 in Fig. 13, 145 in Fig. 20) of the image decoding devices described before as the embodiments 3, 4 and 8.

Referring to Fig. 23E, a memory 171 stores wavelet transform coefficients necessary for decoding one tile and an inverse wavelet transform portion 172 performs the composition of subbands.

An image that must be decoded is assumed to be that shown in Fig. 23B. When performing the wavelet transform of the image without decomposition into tiles, it is necessary to store all wavelet transform coefficients as shown in Fig. 23A. On the contrary, when decoding an image decomposed into tiles as shown in Fig. 23D, the image decoding device can operate using a memory 171 storing the limited number of wavelet transform coefficients as shown in Fig. 23C. The necessary memory capacity can be considerably saved.

All the above-described embodiments can be provided with a plurality of subband-decomposition filters that are adaptively switched over one another to use in the process of wavelet transform coding.

The subband decomposition filters mean low-pass filters and high-pass filters for decomposing an image into subbands





performs wavelet encoding of the input image on a tile-by-tile basis and outputs coded information. This tile wavelet coding portion 201 also outputs tile-decomposition information, subband information and flag information.

A tile-management-information generating portion 203 receives the tile-decomposition information, the subband information and the flag information, and it prepares and provides management information including a combination of the above inputs. A coded data integration portion 107 outputs encoded data which combine the coded information and the management information.

In the tile wavelet-coding portion 201, an input original image is decomposed into tiles by the tile decomposition portion 101 and the decomposed image (tiles) is input to a terminal 0 of a first switch 204. The original image is input to a terminal 1 of the first switch 204. Either of two images through the switch 204 is input to a wavelet transform coding portion 207.

The wavelet transform coding portion 207 performs wavelet encoding of the input image. The output of a first wavelet transform portion 208 is input to a quantizing portion 103 through a second switch 205 or to the quantizing portion 103 through a tile-composing portion 132.

The operation of the first wavelet transform portion 208 is similar to the wavelet transform portion 102 of the embodiment 1 described with reference to Fig. 8. So, the portion





portion 208 or the second wavelet-transform portion 305 in the wavelet transform coding portion and outputs a flag indicating the selection made.

At the same time, the above selection causes the first switch 303 or the second switch 304 to turn ON. Once the first switch was turned ON, the decomposed image is inputted to the first wavelet transform portion 208 whereby the same coding process as made in the embodiment 1 is performed. Once the second switch 304 was selected, the image decomposed into tiles with peripheral pixels is inputted to the second wavelet-transform portion 305 whereby the coding process of the embodiment 5 is performed.

Thus, the image coding device can process an input image on a tile-by-tile basis and can encode the image by selectively applying the simple coding method of the embodiment 1 or the tile-boundary distortionless coding method of the embodiment 5, (by which each tile can be encoded without distortion of its boundary).

Another exemplary image coding device according to the embodiment 12 is shown in Fig. 26, which is capable of selectively applying three different coding modes: methods of the embodiments 1, 5 and 7.

As shown in Fig. 26, this image coding device differs in construction from the image coding device of Fig. 25 by including a tile composing portion 132 and switching circuitry for realizing the coding mode of the embodiment 7. The operation

of this device excepting a tile wavelet transform coding portion 401 and a wavelet transform coding portion 407 is similar to that of the device of Fig. 24, so further description of the portions is omitted.

The wavelet transform coding portion 407 performs wavelet encoding of an input image and outputs coded information of the image. The output of a first wavelet transform portion 308 is inputted to a quantizing portion 103 through a third switch 405 or further through a tile-composing portion 132. The output of a second wavelet-transform portion 305 is inputted directly to the quantizing portion 103.

In the tile wavelet-coding portion 401, the input image is inputted directly to a terminal 0 of the first switch 403. Alternatively, it is decomposed into tiles and then inputted to a terminal 1 of the first switch 403, or it is decomposed into tiles each including necessary peripheral pixels and then inputted to a terminal 2 of the switch 403.

These images are transferred to a first wavelet-transforming portion 308 or a second wavelet-transforming portion 305 through the second switch 404. The image data is quantized in a quantizing portion 103 and encoded in an entropy-coding portion 104 wherefrom coded information is outputted.

A flag generating portion 402 controls the first, second, third and fourth switches 403, 404, 405, 406 to selectively switch the coding modes 0, 1 and 2. The mode numbers are

indicated at terminals of the switches 403, 404, 405 and 406 respectively in Fig. 26.

When the first switch 403 is connected to the terminal 0, all remaining switches 404, 405 and 406 are also connected to their terminals 0. With the switches 403-406 connected to the terminals 0, the image coding device encodes the input image by applying the coding mode of the embodiment 7.

When the switches 403-406 are all connected to their terminals 1, the image coding device encodes the input image by applying the coding mode of the embodiment 1. When the first, second and fourth switches 403, 404, 406 are connected to their terminal 2, the image coding device encodes the input image by using the coding mode of the embodiment 5.

Thus, the image coding device can process an input image on a tile-by-tile basis and can also encode the image by selectively applying one of three coding modes: the simple tile-image-coding method of the embodiment 1, the tile-boundary distortionless coding method of the embodiment 5 or 7, (by which each tile can be encoded without distortion of its boundary).

An image decoding device according to another embodiment 13 of the present invention is described below. The input to this device is coded data encoded by the image coding device according to the embodiment 12 of the present invention. The input data is decoded by this device by applying one of predetermined modes of decoding.

Fig. 27 is a block diagram of an exemplary image decoding device according to the embodiment 13, which is capable of decoding coded data generated by the image decoding device (embodiment 13) by selectively applying two coding methods used in the embodiments 1 and 7.

Referring to Fig. 27, coded information and management information are separated each other at a management-information separating portion 111 and inputted to a tile wavelet decoding portion 501 that in turn performs tile-by-tile decoding of the coded data using the management information and outputs a decoded image.

The coded data is inputted to a wavelet transform decoding portion 502 whereby it is wavelet-decoded. The image decoded by the wavelet transform decoding portion 502 is outputted directly by a second switch 504 or outputted through a tile-combining portion 117.

In the wavelet transform decoding portion 502, the output of an inverse quantizing portion 114 is applied to a first inverse wavelet-transform portion 506 through a first switch 503 or to the first inverse wavelet transform portion 506 through a wavelet-coefficient rearranging portion 155.

The operation of the first inverse wavelet-transform portion 506 is similar to that of the inverse wavelet-transforming portion 115 in the embodiment 3, so further description is omitted.

A flag-generating portion 505 extracts flags for





The wavelet transform decoding portion 602 performs wavelet decoding of input coded information. The output of an inverse quantizing portion 114 through a first switch 604 is inputted to a first inverse wavelet transform portion 506 or a second inverse transforming portion 603.

The output of the first inverse wavelet transform portion 506 is transferred to a tile composing portion 117 and the output of the second inverse wavelet transform portion 603 is transferred to a tile integrating portion 147.

The operation of the second inverse wavelet transforming portion 603 is similar to the inverse wavelet transform portion 145 of the embodiment 8 described with reference to Fig. 20, so further description is omitted.

In the tile wavelet decoding portion 601, the wavelet transform decoding portion 602 performs wavelet decoding of the coded information and outputs the decoded information to the tile composing portion 117 or the tile integrating portion 147. A decoded image is now reproduced.

On the other hand, a flag-generating portion 605 extracts a flag from the management information and controls the operation of a first switch 604 by the extracted flag. With the switch 604 connected to its terminal 0, the image decoding device performs the same decoding operation that the embodiment 3 does. With the switch 604 connected to its terminal 1, the image decoding device performs the same decoding operation that the embodiment 8 does.



it is transferred to a second inverse transforming portion 603 through a terminal 2 of the first switch 703.

The output of the first inverse wavelet-transforming portion 506 is transferred to a tile-composing portion 117 through a second switch 704 or a decoded image is directly outputted. The output of the second inverse wavelet-transform portion 603 is transferred to a tile-integrating portion 147. The operation of other components is similar to that of like components of the wavelet-decoding portion 602 (Fig. 28), so further description is omitted.

In the tile wavelet decoding portion 701, a flag extracting portion 705 extracts flags for controlling the first switch 703 and the second switch 704 from the management information. The remaining management information is inputted to the tile-composing portion 117 and the tile-integrating portion 147.

With the switches 703 and 704 connected to its terminal 0, the image decoding device performs the same decoding operation that the embodiment 3 does. With the switches 703 and 704 connected to its terminal 1, the image decoding device performs the same decoding operation that the embodiment 9 does. When the first switch 703 is connected to its terminal 2, the device performs, the same decoding operation that the embodiment 8 does irrespective of the position of the second switch 704.

Thus, the image decoding device according to the embodiment

13 can process coded image data on a tile-by-tile basis and can also decode the image by selectively applying three decoding modes: the simple tile-image-decoding method of the embodiment 3 and the tile-boundary distortionless decoding method of the embodiments 8 and 9, (by which each tile can be encoded without distortion of its boundary).

An image coding device is described below as an embodiment 14 of the present invention. In this embodiment, tile management information including information for identifying (distinguishing) tiles is utilized to realize high-speed decoding of any objective tile.

Figure 30 is a block diagram showing an exemplary image coding device according to the embodiment 14. Referring to Fig. 30, a tile wavelet-coding portion 801 performs wavelet encoding of an input original image on a tile-by-tile basis, and it generates coded information and management information such as tile-decomposition information, flag information and subband information.

An ID generating portion 802 generates ID information for identifying each tile. Management information generating portion 803 generates management information by combining the management information with the ID information. A coded-data combining portion 804 generates coded data by combining the coded information with the management information and placing a tile-information start code at the head of information of each tile.

Figure 31A shows an example of the coded data format that defines each tile information consisting of a tile-information start code, management information (tile header) and coded data. The tile wavelet-coding portion 801 can be commonly used for image coding devices according to embodiments 1, 2, 5, 6, 7, 10, 12 and 14.

To distinguish tiles into which an original image was decomposed, ID numbers (e.g., 1, 2, ...) are assigned to tiles arranged in a sequence from the top left as shown Fig. 31. Tiles having ID numbers can be coded in any order and rearranged after coding. Moreover, the ID generating portion 802 may be omitted if the order of tiles to be encoded is predetermined.

The location of each tile can be found by its start code or by its data size (coded information plus tile header).

Figure 32 is a block diagram of another exemplary image coding device according to the embodiment 14. This image coding device differs from the device of Fig. 30 only by the provision of a data-size calculating portion 811, so the portions other than the calculating portion 811 and the management-information generating portion 812 are omitted from the scope of further description.

Referring to Fig. 32, the data-size calculating portion 811 calculates a size of coded data for each tile and outputs the calculation result. The management information generating portion 812 prepares management information consisting of management information, ID information and a coded tile-data



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according to the embodiment 14, which can realize the same effects as the above and which differs from the above device of Fig. 32 by the provision of a coded data storing portion 831 and a management information storing portion 832. Therefore, all components other than the coded-data storing portion 831, the management information storing portion 832 and a coded data combining portion 833 are omitted from further description.

Referring to Fig. 34, coded information outputted from a tile wavelet coding portion 801 are temporally stored in the coded-data storing portion 831. The management information storing portion 832 stores tile management information generated by the management-information generating portion 812. It extracts tile-size data from the tile-management-information, sends the data to the coded data combining portion 833 and then outputs the remaining management information.

First, the coded data-combining portion 833 outputs all the data size values for all tiles and then outputs remaining management information combined with coded information.

According to the embodiment 14 of the present invention, it is possible to immediately retrieve coded information of any desirable tile to be decoded.

An image decoding device is described below as another embodiment 15 of the present invention. Figure 35 is a block diagram of an image decoding device according to the embodiment 15, which is capable of decoding coded data encoded and supplied by the image coding device according to the embodiment 14.

Referring to Fig. 35, an objective-tile deciding portion 903 decides an ID of an objective tile to be decoded according to the user's request. A management-information separating portion 906 retrieves a start code indicating the head of the objective-tile coded information in a coded-data sequence and separates the objective tile management information from the objective-tile coded-information.

Based on the management information, a data skip control portion 902 decides whether the ID of the tile to be decoded matches the ID decided by the deciding portion 903. If two IDs match, the portion 902 turns on both a first switch 905 and a second switch 904. Consequently, a tile wavelet-decoding portion 901 can decode the selected tile only.

If the tile management information includes each tile-data size, the management-information separating portion 906 has no need to search tile-data heads and can find the location of the objective tile data head by skipping the unnecessary amount. The tile wavelet-decoding portion 901 can be commonly used in the image decoding devices according to the embodiments 3, 4, 8, 9, 11, 13 and 15.

According to the embodiment 15, it is possible to immediately retrieve and decode the coded data of the object tile by using only the tile head management information without decoding any other coded data.

An image coding device is now described below as another embodiment 16 of the present invention, which can provide coded



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tile images that can be decoded immediately to reproduce a single objective tile image as well as adjacent tile images by using tile-management information including neighbors' information.

Figure 36A is a block diagram of an exemplary image coding device according to the embodiment 16. This device differs from the embodiment 14 of Fig. 30 by the addition of an adjacent tile ID deciding portion 841 and by the operation of a management-information generating portion 841. Other portions are similar to those of the embodiment 14 and omitted from the scope of further description.

A tile wavelet-coding portion 841 can be commonly used in the image coding devices of the embodiments 5, 6, 7, 10, 12 and 14.

Referring to Fig. 36A, the adjacent tile ID deciding portion 841 decides IDs of adjacent tiles necessary for decoding an objective tile according to tile decomposition information, flag information, subband information and tile IDs produced by an ID generating portion 802. A management-information generating portion 842 prepares management information containing tile decomposition information, flag information, subband information and tile ID with adjacent tiles IDs.

Since all adjacent tiles necessary for coding an objective tile are not necessarily given IDs, the number of adjacent IDs to be produced by the peripheral tile ID deciding portion 841

may be limited to, for example, two neighbors existing left above and left below the objective tile as shown in Fig. 36B.

In the coded data format of Fig. 31A, the management information (tile header) may include an objective tile ID and adjacent tiles' IDs.

Figure 37 is a block diagram of an exemplary image coding device according to the embodiment 16 of the present invention, which is intended to encode tile images that may be rapidly retrieved for decoding by using management information including each objective tile ID with neighbors' IDs. This image coding device is similar in construction to embodiment 14 of Fig. 34 but differs from the embodiment 14 by the absence of the management information storing portion 832 and by the presence of a data-size storing portion 853, relative position calculating portion 852 and information storing buffer 854.

The operation of this image coding device is similar to the embodiment 14 except the operation with the data-size storing portion 851, relative position calculating portion 852, information storing buffer 854, management information generating portion 853 and ID generating portion 855. Therefore, like components are not described further.

Referring to Fig. 37, coded information outputted from a tile wavelet coding portion 801 are all stored in a coded data storing buffer 831. Tile-decomposition information, flag information and subband information from the tile wavelet coding portion 801 are all stored in the information storing





necessary neighbors.

If the predetermined number (e.g., two dotted tiles in Fig. 36B) of peripheral IDs decoded in the management information is smaller than the number of necessary peripheral tiles (e.g., six unshaded neighbors in Fig. 36B), IDs of the remaining necessary neighbors are decided from the decoded IDs of the adjacent tiles.

The tile wavelet-decoding portion 901 can be commonly used in embodiments 8, 9, 11, 13 and 15.

The above system can immediately decode any objective tile and necessary adjacent tiles by decoding only the management information put at the head of the coded data. It has no need of decoding all the coded data.

#### THE POSSIBLE INDUSTRIAL APPLICATIONS

As described herein, following aspects are brought according to the present invention.

In one aspect of the present invention, an image coding device can independently encode each of tiles of an original image, thus providing coded tile images that can be separately treated thereafter. If any of coded tile must be further processed, it can be separately, processed and encoded again with no need of using adjacent pixels. Thus, simple independent encoding and decoding of image tiles is realized.

In another aspect of the present invention, an image decoding device can decode only a desirable coded tile image

with no need of decoding any other coded data, thereby minimizing the processing load.

In another aspect of the present invention, in spite of increasing of the coded-data size due to encoding an objective tile image including adjacent pixels, an image decoding device decodes the coded tile image by superposing adjacent pixel values on overlaps, suppressing possible boundary distortion of the tile image.

In still another aspect of the present invention, an image coding device can encode tile images using pixel information on neighboring tiles, achieving high efficiency of image encoding using the correlation between tiles. This can also suppress possible boundary distortion of the tile images.

In another aspect of the present invention, an image coding device can effectively encode a part (plural tiles) of a whole image by performing wavelet transform of only selected tiles, and its wavelet transform is very compact.

An image decoding device responding to the above can also realize compact inverse wavelet transform of coded tile images.

In a further aspect of the present invention, an image coding device can decide exclusion of distant pixels from the scope of adjacent pixels for calculation. This minimizes the number of filtering operations and wavelet-transform operations.

A whole image is wavelet transformed at a time and then wavelet transformed coefficients are rearranged to compose

respective tiles. This eliminates the need of iterating the wavelet-transform for each tile.

In another aspect of the present invention, an image decoding device can rearrange coded data (decomposed for each tile) corresponding to an objective tile and then perform inverse wavelet transform of the coded data at a time, thus eliminating the need of repeating inverse wavelet transform for each tile.

Conventional arts demand a large capacity of a memory for holding wavelet transformed coefficients to correspond to resolution of an original image. In contrast to the above, an image coding device according to one aspect of the present invention can use, irrespective of the original image size, a memory which can store only wavelet transform coefficients for capacity corresponds to the size of a tile or tiles for a tile or tiles being currently encoded. This can realize a considerable saving of memory capacity needed.

In another aspect of the present invention, an image decoding device can also use a memory having the capacity limited to a tile size for storing wavelet transform coefficients.

In a further aspect of the present invention, an image coding device can conduct wavelet transform by selectively applying plural suitable filters for decomposing an objective tile image into subbands, thus realizing optimal wavelet transform of the objective tile with the best balance between

the image quality and the processing load.

In a further aspect of the present invention, an image decoding device can conduct inverse wavelet transform by selectively applying plural suitable filters for composing subbands, which respond to the subband decomposing filters. Thus, the device realizes the optimal inverse wavelet transform of each tile to be decoded.

In a still further aspect of the present invention, an image decoding device can selectively apply two wavelet transform modes: one for each tile with or without adjacent pixels and the other for each image with or without adjacent pixels. Two modes can be selected in accordance with the input image quality to minimize the increase of transform operations and deterioration of the image quality.

In another aspect of the present invention, an image decoding device can easily retrieve coded information of an objective tile to be decoded by searching management information well organized for identifying every tile. Therefore, it can realize high-speed retrieval and effective decoding of only plural tiles necessary for reproducing an area (several tiles) of a whole image.

In still another aspect of the present invention, an image decoding device can easily retrieve coded information of an objective tile and coded information of adjacent tiles necessary for decoding the objective tile by using management information well organized for identifying every tile.



Therefore, only an area (several tiles) of a whole image can be rapidly reproduced by decoding only necessary tiles.

High efficient coding/decoding of image tiles using adjacent pixel information is also achieved by utilizing the effect of correlative effect of the pixels.

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